CHAPTER SEVEN
WATER QUALITY BENEFITS

7.1 NWPCAM ANALYSIS METHODOLOGY

7.1.1 Description of the NWPCAM Model

The National Water Pollution Control Assessment Model (NWPCAM) is a national surface-water quality model that simulates water quality improvements and economic benefits that result from water pollution control policies. NWPCAM is designed to characterize water quality for the nation's network of rivers, streams, and lakes. NWPCAM incorporates a water quality model into a system designed for conducting national policy simulations and benefits assessments. NWPCAM is able to translate spatially varying water quality changes into willingness-to-pay values that reflect the value that individuals place on water quality improvements. In this way, NWPCAM is capable of deriving economic benefits estimates for a wide variety of water pollution control policies.

NWPCAM's national-scale framework allows hydraulic transport, routing, and connectivity of surface waters to be simulated in the 48 contiguous states. The model can be used to characterize source loadings (e.g., point sources) under a number of alternative policy scenarios (e.g., loadings with controls). These loadings are processed through the NWPCAM water quality modeling system to estimate instream pollutant concentrations on a detailed spatial scale and to estimate policy-induced changes in water quality. The model incorporates routines to translate estimated concentrations into a six-parameter water quality index (WQI6) and an overall use support determination that provide composite measures of overall water quality. The composite measures allow for the calculation of economic benefits associated with the estimated water quality improvements. NWPCAM can be used to assess both the water quality impacts and the social welfare implications of alternative policy scenarios.

NWPCAM 2.1 uses the Reach File 3 (RF3) database routing and connectivity information to assign hydrologic sequencing numbers to each RF3 reach. The RF3 network includes 1,817,988 reaches totaling 2,655,437 miles within the contiguous 48 states. A subset of this network, including only streams greater than 10 miles in length and the small streams connecting them, was extracted for this analysis. The subset, Reach File 3 Lite (RF3Lite) database, capitalizes on the information in the RF3 database while limiting the computational burden of coping with the full network. The RF3Lite network includes 575,991 reaches totaling 835,312 miles, or approximately one-third of the RF3 network. NWPCAM 2.1 includes instream routing routines to connect point source and nonpoint source loads from the RF3 network to RF3Lite. These routines rely primarily on first-order kinetics, using RF3 time of travel estimates to model processes occurring outside of the RF3Lite network.

NWPCAM 2.1 simulates 11 water quality parameters:

- Biochemical oxygen demand (BOD)
- Total organic nitrogen (TON)
- Ammonia (NH_3)
- Nitrate-N and Nitrite-N (NO_x)
- Total organic phosphorous (TOP)
- Ortho-phosphate (PO_4)
- Algae chlorophyll (CHLA)
- Dissolved oxygen (DO)
- Chlorides (Cl)
- Total suspended solids (TSS)
- Fecal coliform bacteria (FEC)

The original water quality index included nine indicators of water quality (McClelland, 1974). BOD, DO, FEC, NO_x, PO_4 and TSS are used in the WQI6. McClelland (1974) used turbidity in her assessment rather than TSS. To incorporate TSS, a regression equation was used to convert the original graph of water quality against turbidity into a graph of water quality against TSS. The water quality index is multiplicative so the weights given to all of the components must sum to one. Thus, the weights for the WQI6 components were revised to sum to one based on their weights in the original water quality index.

EPA focused on sediment loads from construction sites. Site experience was generalized using appropriate adaptations to different weather, slope, and soil conditions in different regions of the country to estimate changes in sediment loads. Details of this analysis may be found in the Development

Document (U.S. EPA, 2004, Chapter Eight). The analysis generated an estimate of the change in total suspended solids for 1,644 watersheds. To avoid double-counting, a portion of the background non-point source TSS loads were removed from the model for each land cover cell devoted to construction. National baseline TSS loads from construction sites were estimated to be 5.7 million metric tons per year. Option 4 is estimated to reduce this total loading to 4.9 million metric tons per year.

NWPCAM 2.1 uses this loading data to generate input and output files for thousands of Eutro-Water Quality Analysis Simulation Program, Version 5 (WASP5) model runs. Eutro-WASP5 calculates the decay and dispersion dynamics of the water quality indicators of WQI6 by modeling the mixing, exchange, chemical, and biological processes occurring as the effluent flows through the surface-water network. Many characteristics of the waterways and their environment contribute to the process models.

7.1.2 Valuation of Water Quality Changes

The correct benefit measure to compare with social costs is the change in producer and consumer surplus ensuing from a change in environmental quality. One way to measure this quantity is to elicit individuals' willingness to pay for the change. Most benefit assessments in the soil conservation context take an alternative approach using the costs of avoiding the consequences of the environmental harm as a proxy for willingness to pay. This was the approach taken for the benefits assessment of the C&D options at proposal. For assessing the Final Action, however, EPA adopted an alternative survey-based approach.

To value predicted reductions in the pollution of rivers and streams, NWPCAM applies estimates of Americans' willingness to pay for improvements in water quality. The foundation of these estimates is a contingent valuation survey developed by Richard Carson and Robert Mitchell (Carson and Mitchell, 1993). This survey, which is national in scope, characterizes households' annual willingness to pay to improve freshwater resources from baseline conditions to conditions that better enable beneficial uses such as boating, fishing, and swimming. EPA uses the Carson and Mitchell research in two separate analyses:

- First, EPA develops benefits based on the public’s willingness to pay for improvements in water quality that allow discrete movement to higher levels on a “ladder” of potential water uses.

- Second, EPA develops benefits based on a continuous water quality index, WQI6.

In the following section, we discuss these two methods in greater detail. The resulting economic benefit estimates are discussed in Section 7.2, Benefits Assessment Results.

7.1.2.1 Water Quality Ladder Approach

EPA's first approach to relating surface-water conditions to the ability of a body of water to support a particular designated use is based on a water quality ladder. The ability of a water body to support beneficial uses at each step of the water quality ladder is defined by measures of DO, BOD, TSS, and FEC. In order for a body of water to be considered boatable, fishable, or swimmable, it must satisfy the minimum numeric criteria consistent with that use for all modeled parameters. These minimum conditions are the same for all geographic areas. NWPCAM classifies each segment of each modeled river or stream as swimmable, fishable, boatable, or non-supportive of any of these uses. The model calculates the total stream-miles that support each designated use under each set of loadings conditions (i.e., baseline conditions or conditions following implementation of the regulations).

The contingent valuation survey on which this analysis relies examined households’ willingness to pay to maintain or achieve specified levels of water quality in freshwater lakes, rivers, and streams throughout the United States (Carson and Mitchell, 1993). Respondents were presented with the water quality ladder and asked to state how much they would be willing to pay to maintain or achieve various levels of water quality throughout the country.

Applying the willingness-to-pay estimates obtained from the Carson and Mitchell study to analyze the benefits of regulations requires consideration of how households’ willingness to pay for water quality improvements is likely to vary with the extent and location of the resources affected. People are likely to place greater value on improving the quality of water resources that are located nearer to them because less time and expense is typically required to reach nearer resources; as a result, these resources generally provide lower cost and more frequent opportunities for recreation and enjoyment. To reflect this consideration, the analysis separately calculates the benefits of in-state and out-of-state improvements, assuming that households will allocate two-thirds of their willingness-to-pay values to the improvement of in-state waters. In addition, the analysis takes into account the number of stream-miles that improve from one use class to another by scaling household willingness to pay for a given improvement by the proportion of total stream-miles that are projected to make the improvement.

7.1.2.2 Water Quality Index Approach

A key limitation of the water quality ladder approach is that it only values changes in water quality to the extent that they lead to changes in beneficial-use attainment. As a result, the approach may attribute all of the benefits that occur at the thresholds between beneficial use categories to relatively small changes in water quality indicators, while failing to capture the benefits of large changes that occur without crossing the thresholds. In assessing a change in a large number of sources, changes that happen to push a reach over the threshold will balance out those that do not, and the statistical outcome would be a fair measure of willingness to pay. This rule, however, affects relatively few miles of water ways. The limited sample size opens the door for chance changes in a few places to drive the results higher or lower. Furthermore, the use classification is determined by the worst individual water quality parameter. For example, if TSS achieves the boatable criterion but fecal coliform does not, the reach would still be classified as non-boatable. The water quality index approach is designed to address these concerns.

Under the water quality index approach, NWPCAM calculates WQI6. EPA relies on a willingness-to-pay function derived by Carson and Mitchell using their survey results. This equation specifies household willingness to pay for improved water quality as a function of WQI6, household income, household participation in water-based recreation, and respondents' attitudes toward environmental protection. EPA estimates changes in index values using NWPCAM and applies the willingness-to-pay function to estimate benefits. Based on this approach, EPA is able to assess the value of improvements in water quality along the continuous 0 to 100 point scale. As with the water quality ladder approach, the calculation of benefits is developed by state and takes into account differences in willingness to pay for local and non-local water quality improvements (i.e., it assumes households will allocate two-thirds of their willingness to pay for improvements to in-state waters).

Results of the two monetization analyses are presented in Section 7.2. See the Environmental and Economic Benefit Analysis for the concentrated animal feeding operations ELG for a more detailed description of the two valuation approaches and their application (U.S. EPA, 2002, Section 4.6).

7.1.3 Nonquantified Categories of Benefits

Commenters on the proposed C&D regulation cited a number of categories of benefits that were not included in the assessment of the rule. Inadequate data and modeling constraints prevented quantification or monetization of any categories beyond the sediment effects considered in the NWPCAM analysis discussed above. Nevertheless, other effects of the Final Action will generate benefits to society. To organize its discussion of non-quantified benefit categories, EPA considers the path stormwater, sediment, and related pollutants take from a building site to their final deposition. Along this path, excess sediment and water creates costs to society in terms of increased maintenance costs, disamenities, and outright damage. Table 7-1 summarizes the ways in which practices required by this regulation may address categories of social impacts from fugitive sediment. The depth of analysis column indicates whether the effect has been monetized through the NWPCAM process, quantified, or is discussed qualitatively. Given the format of the Mitchell-Carson willingness-to-pay survey, it is difficult to know what respondents were valuing in terms of specific environmental changes. Those identified as monetized in Table 7-1 are categories that individuals may have considered in their responses to the survey.

7.2 BENEFITS ASSESSMENT RESULTS

EPA's purpose in considering Options 2 and 4 is to benefit the nation by improving water quality and the environment. These benefits can be measured in economic terms and balanced against the costs of implementing the incremental regulatory options. The preceding section described many categories of

Table 7-1. Framework of Benefit Categories and Depth of Analysis

Built Environment		
	Create site amenities such as water features	Qualitative
	Encourage development of “green” v. “brown” sites	Qualitative
	Reduce street dredging costs	Qualitative
	Reduce clogging of stormwater conveyance systems - ditches and culverts	Qualitative
	Reduce impacts of construction on stormwater treatment practices	Qualitative
Temporary Sediment Deposition		
	Reduce overland erosion	Qualitative
	Reduce effect of excess sediment on stream benthos and habitat	Quantified
Long-Term Sediment Deposition - Sediment Sinks		
	Reduce filling of wetlands and related habitat effects	Qualitative
	Reduce loss of reservoir capacity	Qualitative
	Reduce filling of navigational channels	Qualitative
	Reduce sedimentation of shellfish beds	Qualitative
Suspended Sediment in the Water Column		
	Improve water quality for recreational use, particularly fishing	Monetized
	Reduced costs to treat drinking water	Monetized
	Reduced costs to treat cooling/process water	Monetized
	Improve the aesthetic appearance of rivers and lakes	Monetized
Nutrients in the Water Column - Eutrophication		
	Reduce excess nutrients that cause lake and estuary habitat change	Qualitative
	Improve water clarity and reduce associated loss in property values	Monetized
	Reduce the frequency of anaerobic events and other fishery impacts	Qualitative
Hydrological Changes		
	Reduce the need for stream restoration by maintaining natural flows	Qualitative
	Reduce damage to bridges and culverts from peak flows	Qualitative
	Reduce the impact on thermal conditions	Qualitative
Non-Use Benefits		
	Bequest, existence, and similar non-use aspects of water quality.	Monetized

benefits that EPA believes would likely be generated by these options. It also described the methodologies EPA developed to measure the benefits of the options. This chapter summarizes the results of that analysis. The first section draws on the Environmental Assessment to show the changes in sediment loads that indicate the environmental effects of the regulation. The second section describes the results of applying these environmental changes to the NWPCAM benefit estimation model described in Section 7.1.

7.2.1 Environmental Assessment Results

The Environmental Assessment used a model watershed approach to estimate TSS in the baseline condition and under the alternative options. TSS is a measure indicating the level of sediment in the water. Sediment is a good indicator of the regulation’s effectiveness both for sedimentation and turbidity effects and because nutrients, metals, and organic compounds enter the environment attached to sediment particles. Table 7-2 shows the estimated difference between sediment tonnage released under the baseline and that released under Option 4.

Option 4 reduces the nationwide total solids loads measured at the land cover cell level (i.e., at the construction site) from 5.7 million metric tons per year to 4.9 million metric tons per year (Miles and Bondelid, 2004). NWPCAM, the water quality model used for this assessment, is based on RF3Lite. Only about 61 percent of TSS generated at construction sites is estimated to reach RF3Lite waters where water quality benefits are measured. The option would generate a 15 percent reduction in the TSS load generated by construction activities. See the Technical Development Document (EPA, 2004) for a more extensive explanation of how the changes in loads were derived.

Table 7-2. Benefit Assessment Summary

Option	Land Cover Cell Load (thousand metric tons/year)	Reach File 3 Lite Load (thousand metric tons/year)	Reduction from Baseline
3 (Baseline)	5,705	3,454	---
4	4,851	2,938	14.9%

Source: Miles and Bondelid, 2003.

7.2.2 Benefits Assessment Results

As discussed in Section 7.1, the sediment loadings drive the NWPCAM/Mitchell-Carson benefit analysis. Table 7-3 shows the monetized benefit estimates using the water quality ladder and water quality index approaches. These figures represent the present value of benefits of Option 4 derived from one year's construction activity. As construction sites are quite short-lived, all of the benefits occur within one year so discounting for the time value of money is moot. This formulation places the benefits in the same terms as the costs developed in Chapter Five.

Table 7-3. Benefit Assessment Summary—Differences from Baseline

Water Quality Ladder Category	Water Quality Ladder Approach ($ Million, 2000)	Water Quality Index Category	Water Quality Index Approach ($ Million, 2000)
Boatable	$ 8.05	<26	$ 0.03
Fishable	$ 14.83	26-70	$ 7.34
Swimmable	$ 4.11	>70	$ 7.10
Total	$ 26.99	Total	$ 14.47

Source: Miles and Bondelid, 2004.

While the water quality index approach includes improvements in many more miles of waterways (9,303 miles) than the water quality ladder approach (803 miles), the improvements generate a smaller total value. Each change in water quality ladder category captures all of the value of the shift from one category to another. Each improvement evaluated under the water quality index generates only a small increment in willingness to pay.

As discussed in Section 7.1, these benefit estimates represent only the fraction of total benefits that can be monetized. Many other results of the regulation will also improve social welfare but could not be reasonably quantified from the available information.

7.3 REFERENCES

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